

Interstellar Emission: Now in 3D

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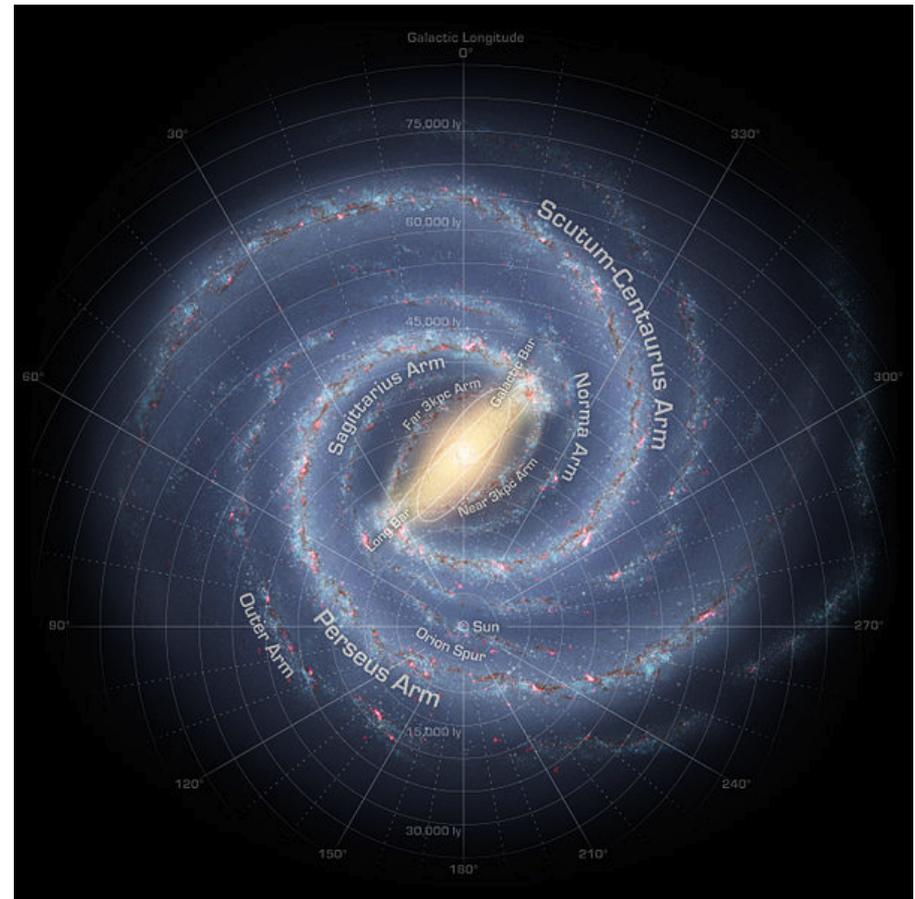
with
Troy Porter and Igor Moskalenko



- CR propagation code that has been in development since the 90s
 - Read all about it at <http://galprop.stanford.edu>
 - You can run it on servers at Stanford through webrun or download the code to run on your own machine
- Development still going strong
 - Latest release is version 54

Current IEM

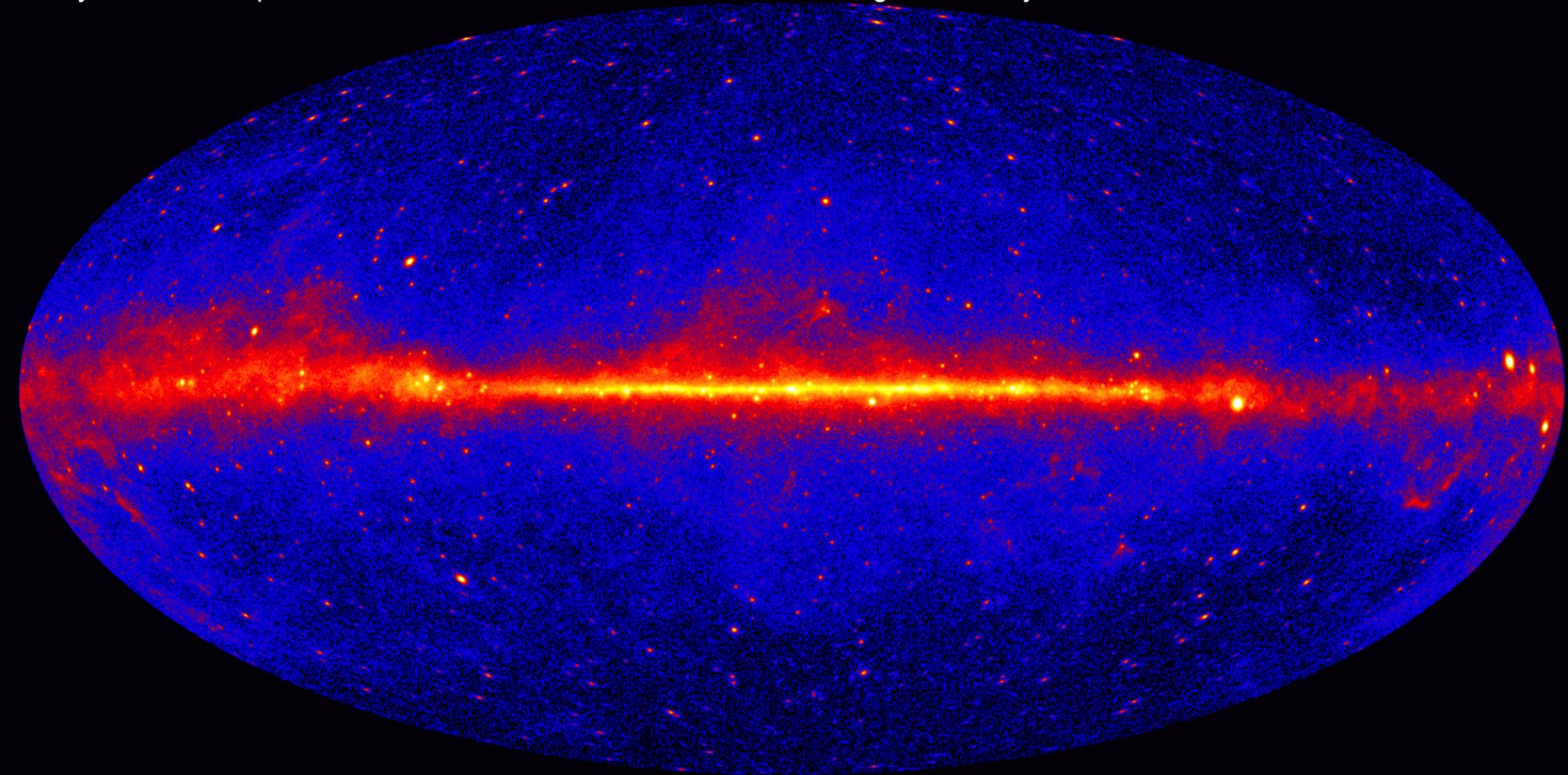
- Technically 3D (longitude, latitude, and energy) with spatial dimension integrated away
 - Assumes a 2D cylindrically symmetric distribution for the CR sources and propagation
- But the Milky-Way is a barred spiral arm galaxy
 - Precise *Fermi*-LAT data clearly indicate that the simple 2D model needs refinement



Artist's view
of the Milky Way.

Fermi-LAT Data

4 year Pass 7 reprocessed Fermi LAT data $> 1\text{GeV}$, front converting events only



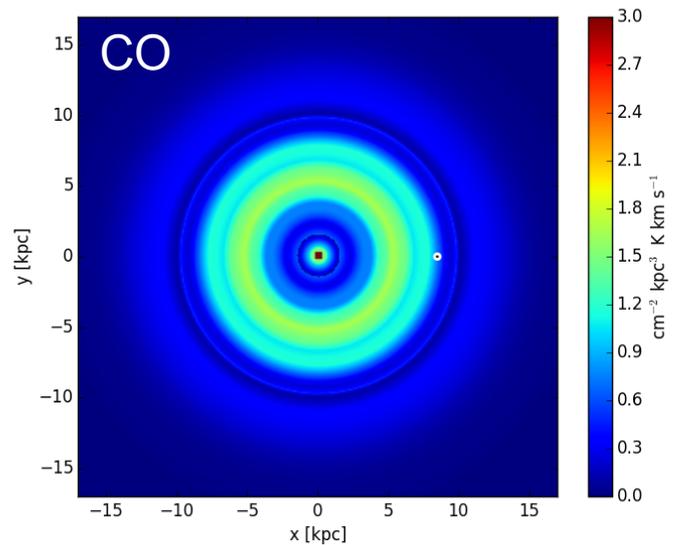
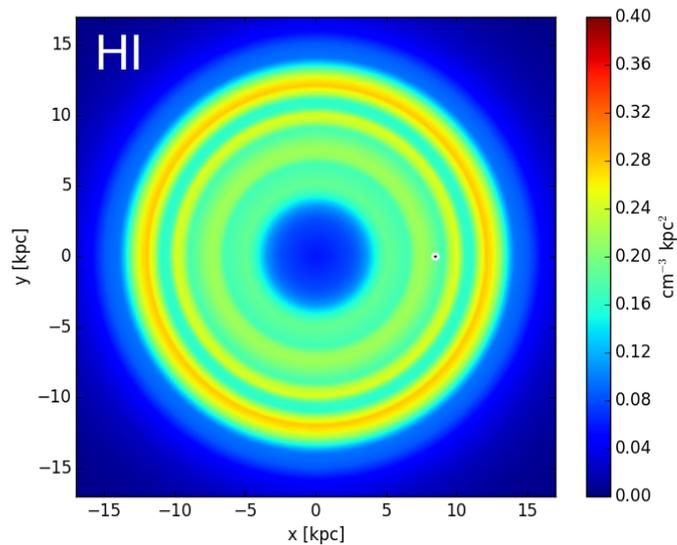
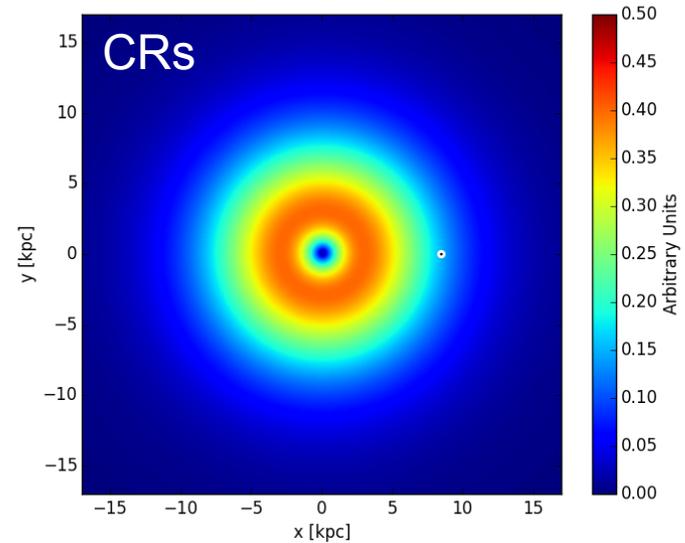
Simple 3D Test Models

- Restricted to modification of gas and CR source distributions
 - ISRF and magnetic field in these models are 2D only
 - 3D magnetic fields available, see E. Orlando's poster
 - Working on 3D ISRF, first trial run finished
- Use 4 symmetric spiral arms and keep the total integrated mass (number of sources) fixed for the gas (CRs)
 - Spiral arm model from Vallee 2014
 - Not tuned to gamma-ray observations
 - Have 3 values for the percentage of mass in arms: 0%, 50%, and 100% for each of gas and CRs for a total of 9 models

| | | |
|----------|-----------|------------|
| CR0 G0 | CR50 G0 | CR100 G0 |
| CR0 G50 | CR50 G50 | CR100 G50 |
| CR0 G100 | CR50 G100 | CR100 G100 |

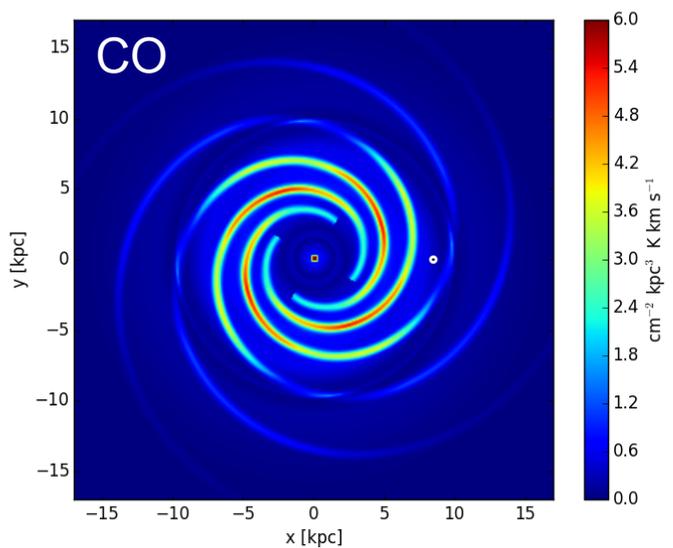
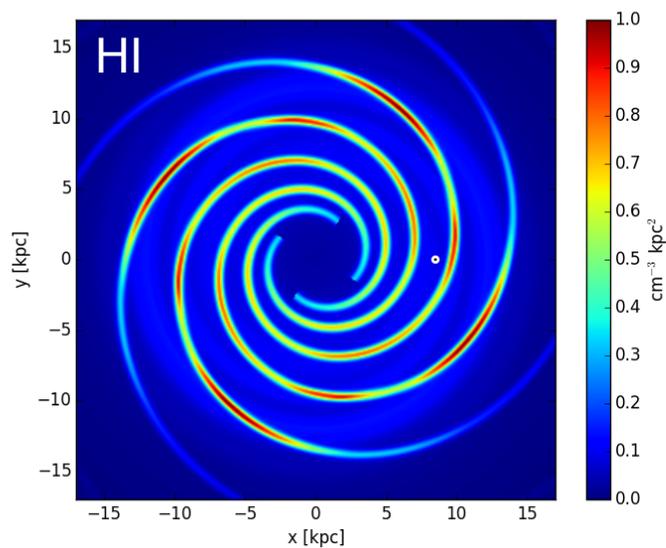
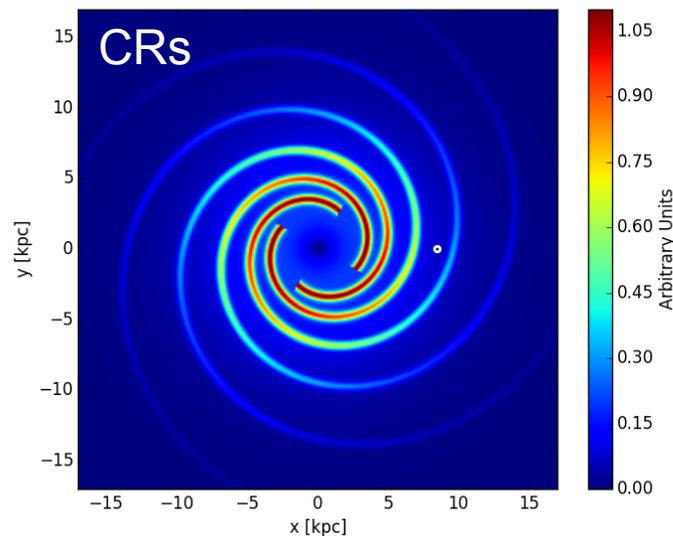
The Models

- Surface density maps of different components
 - 0% in spiral arms => 2D equivalent
 - GALPROP analytic models for HI and CO, typical CR model.



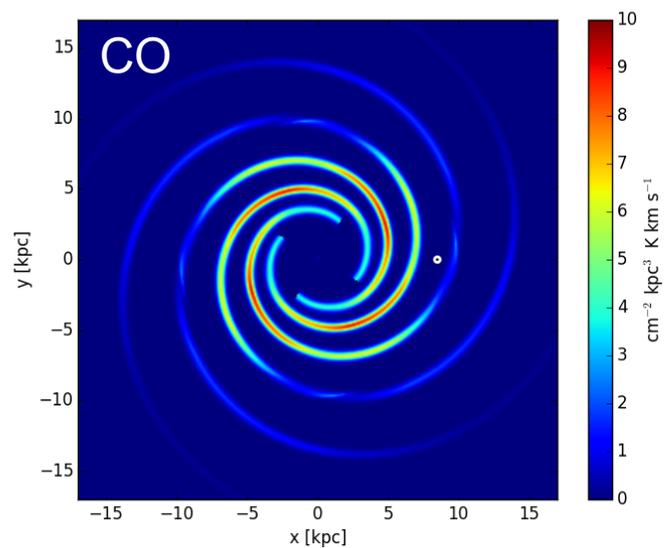
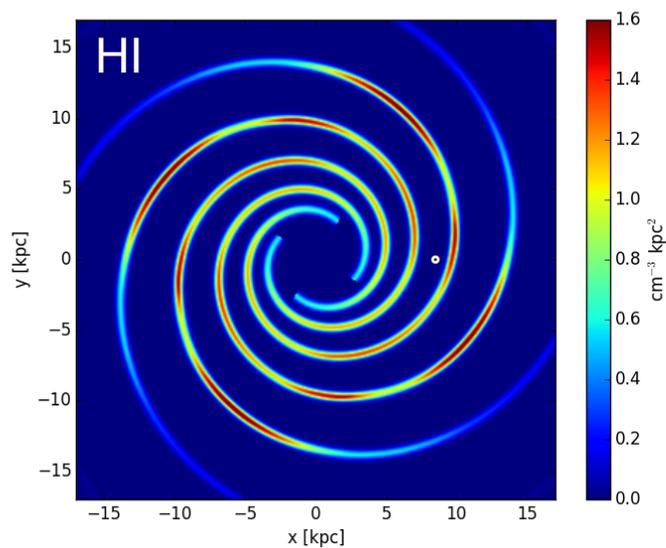
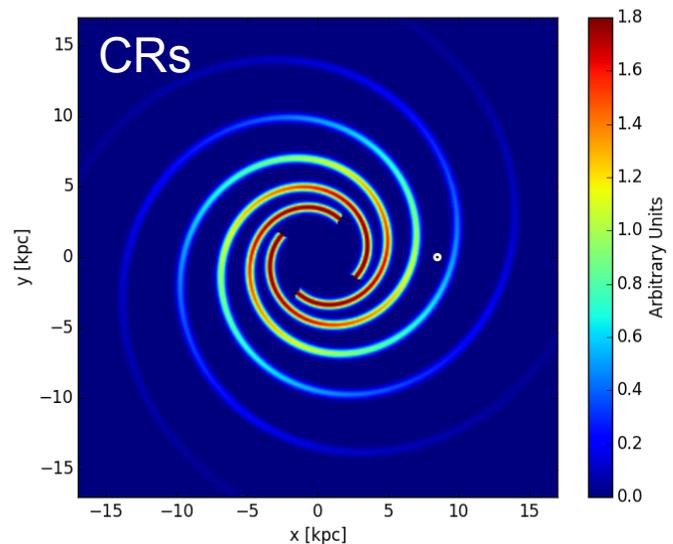
The Models

- Surface density maps of different components
 - 50% in spiral arms



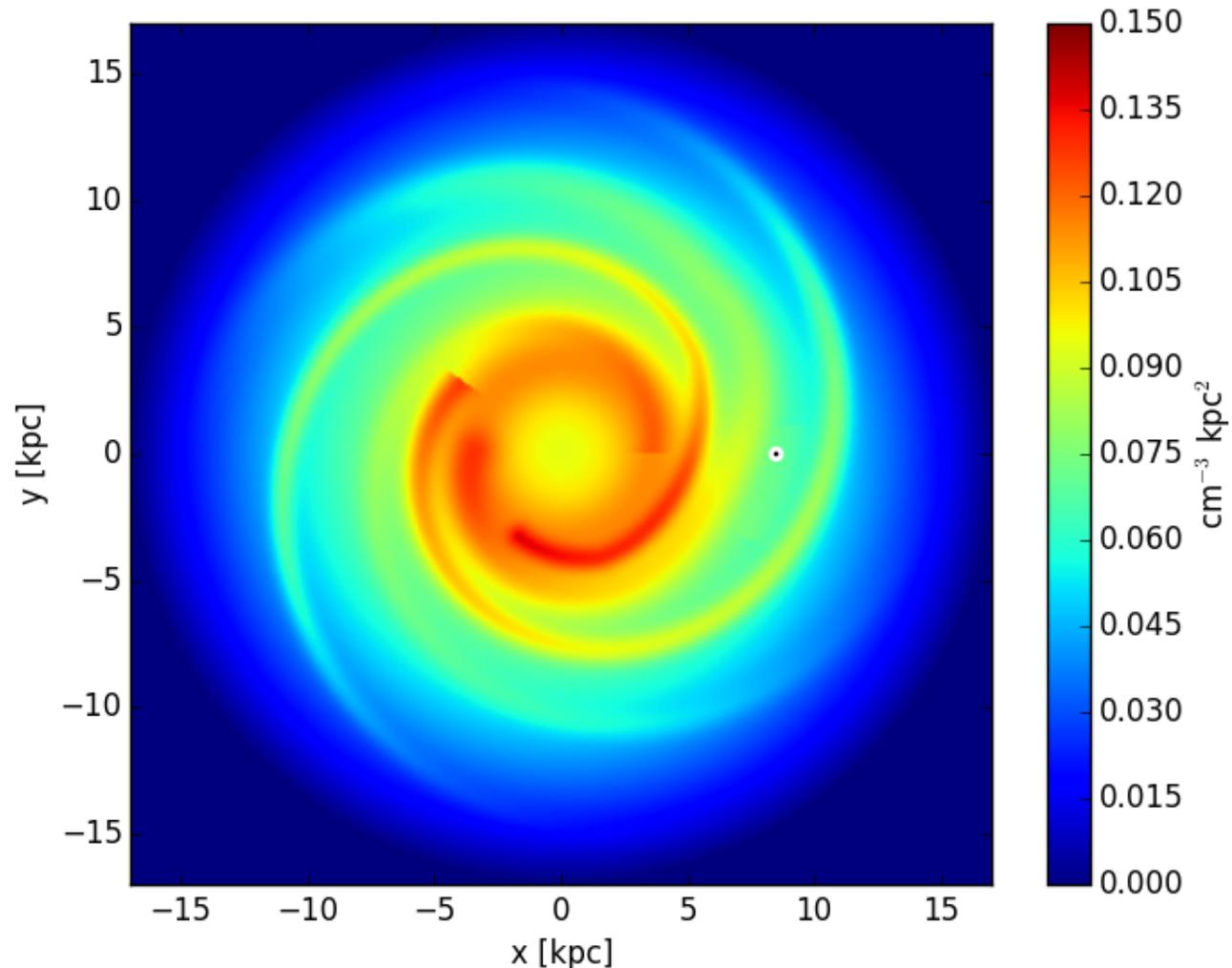
The Models

- Surface density maps of different components
 - 100% in spiral arms

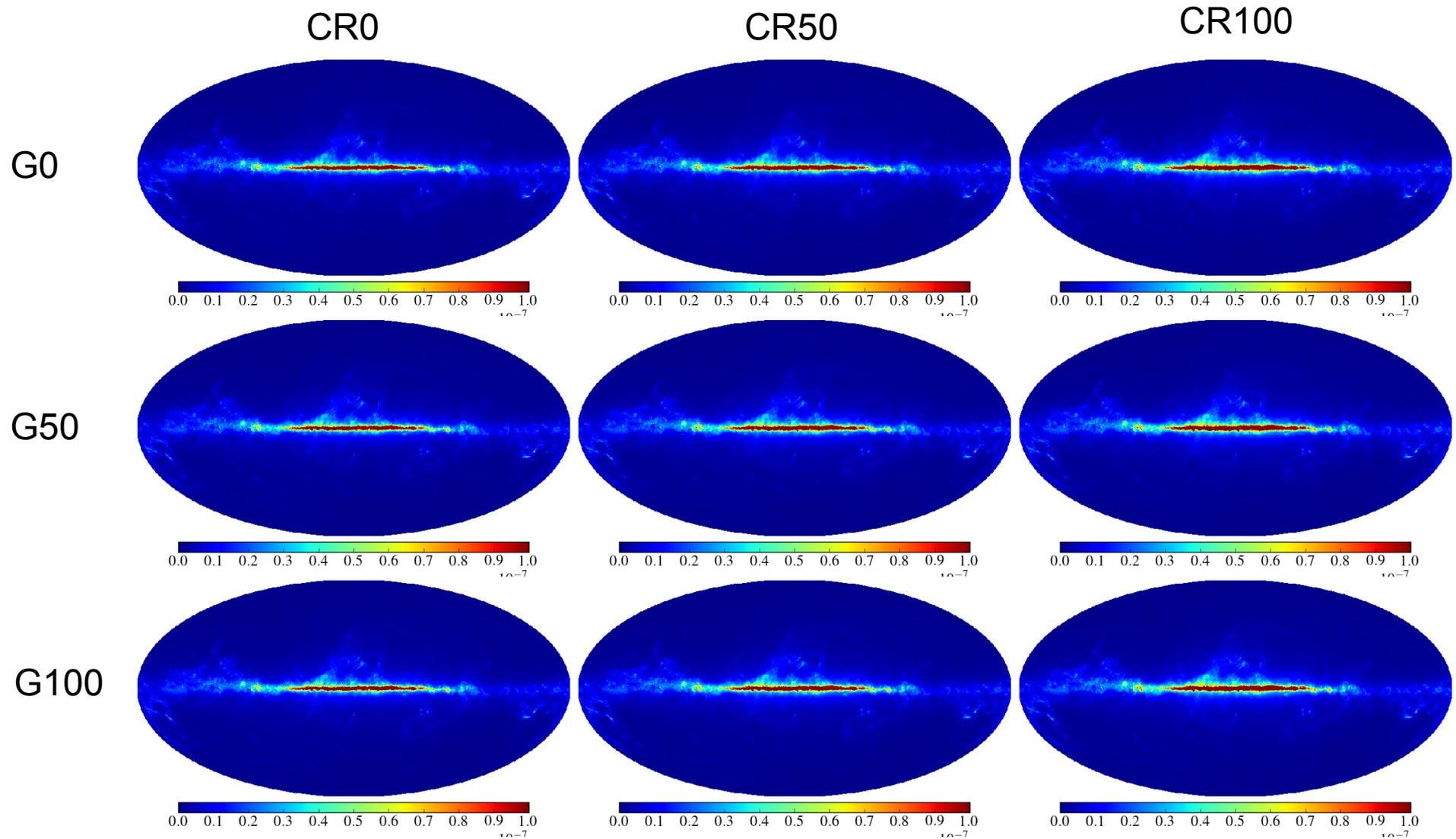


How Realistic Are They?

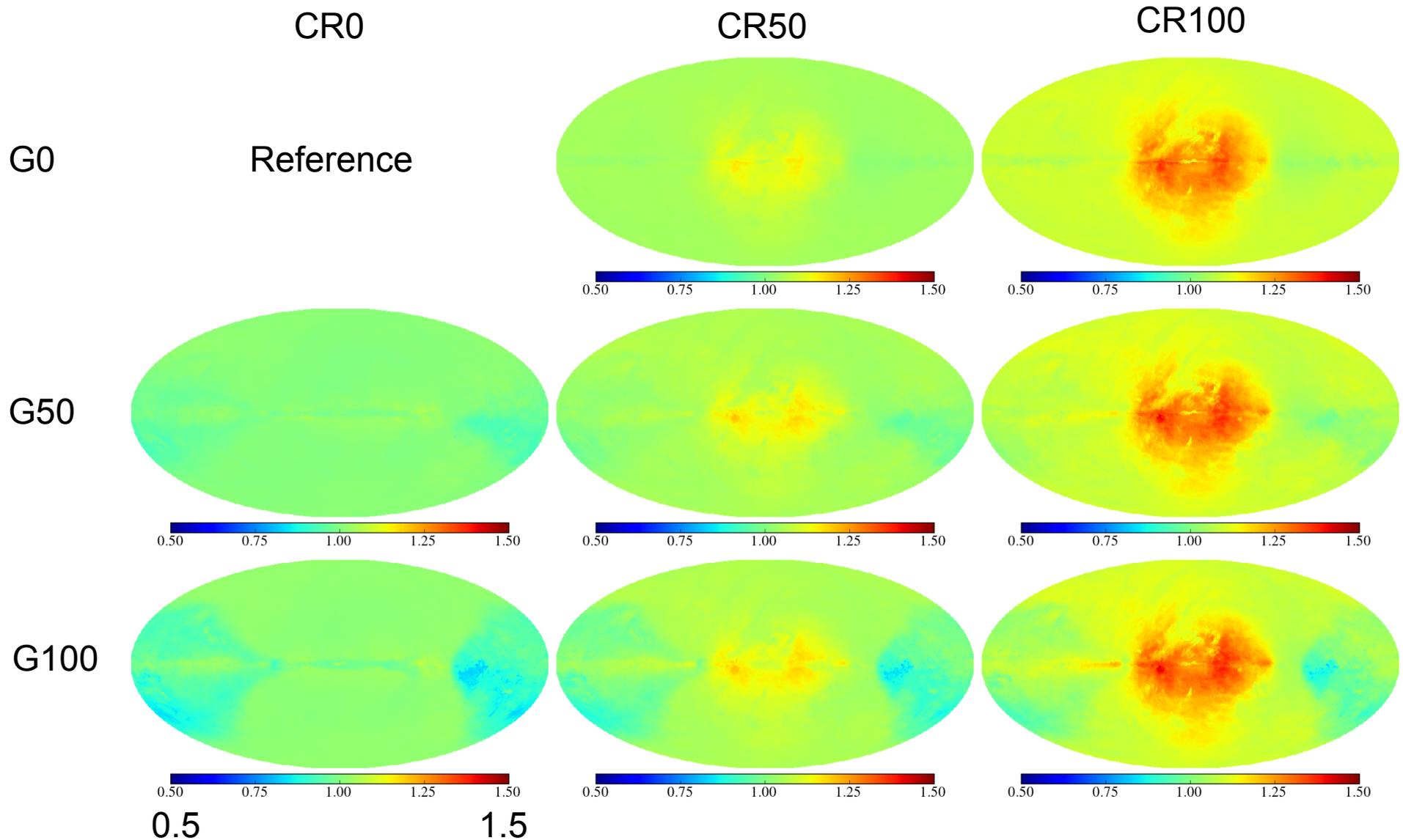
- NE2001 model smoother but more asymmetric arms
 - No blobs included
 - No North-South asymmetry
 - All distributions have the same 3D structure
- Results indicative but more studies required to fully explore the expanded parameter space



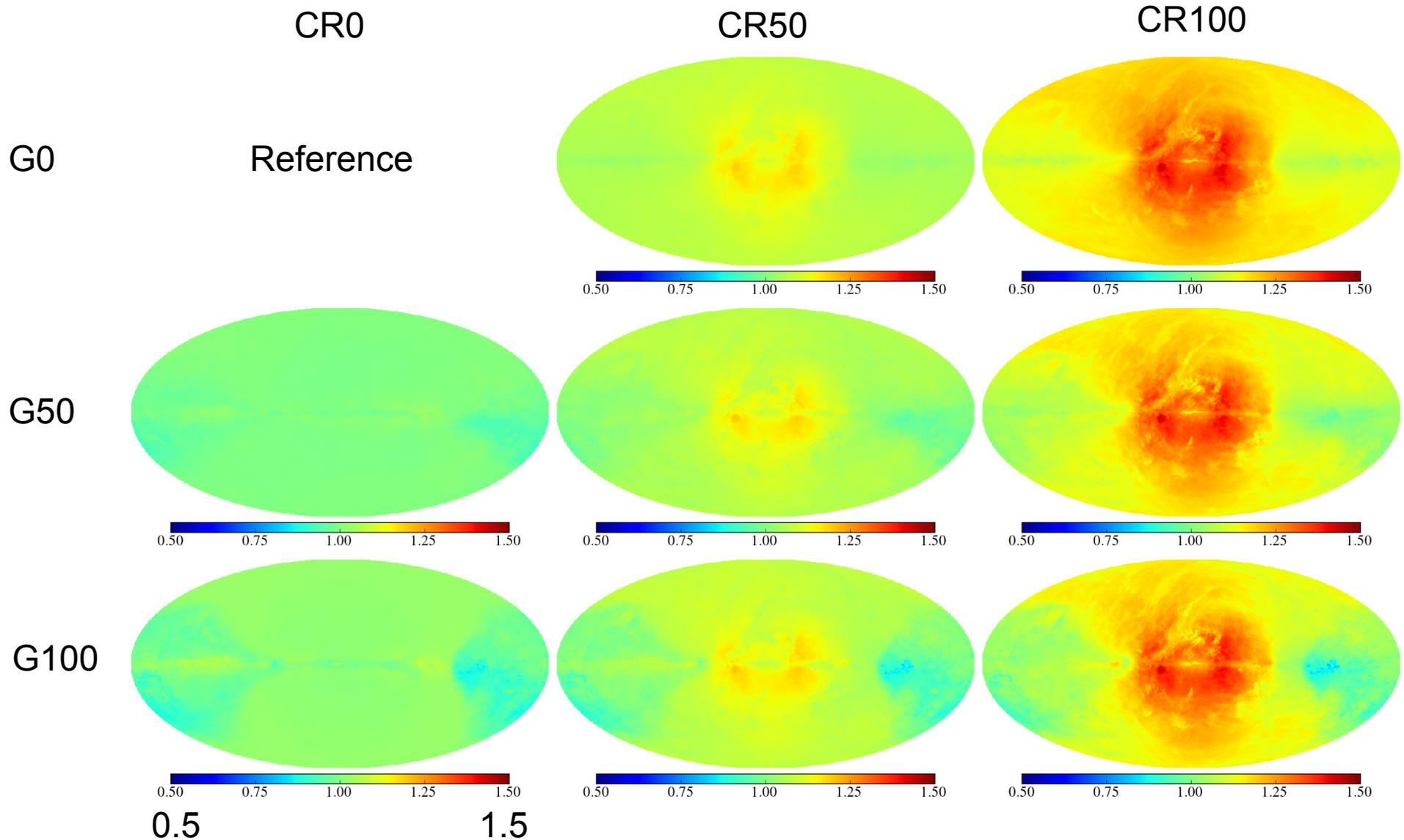
Total IEM Model at 1 GeV



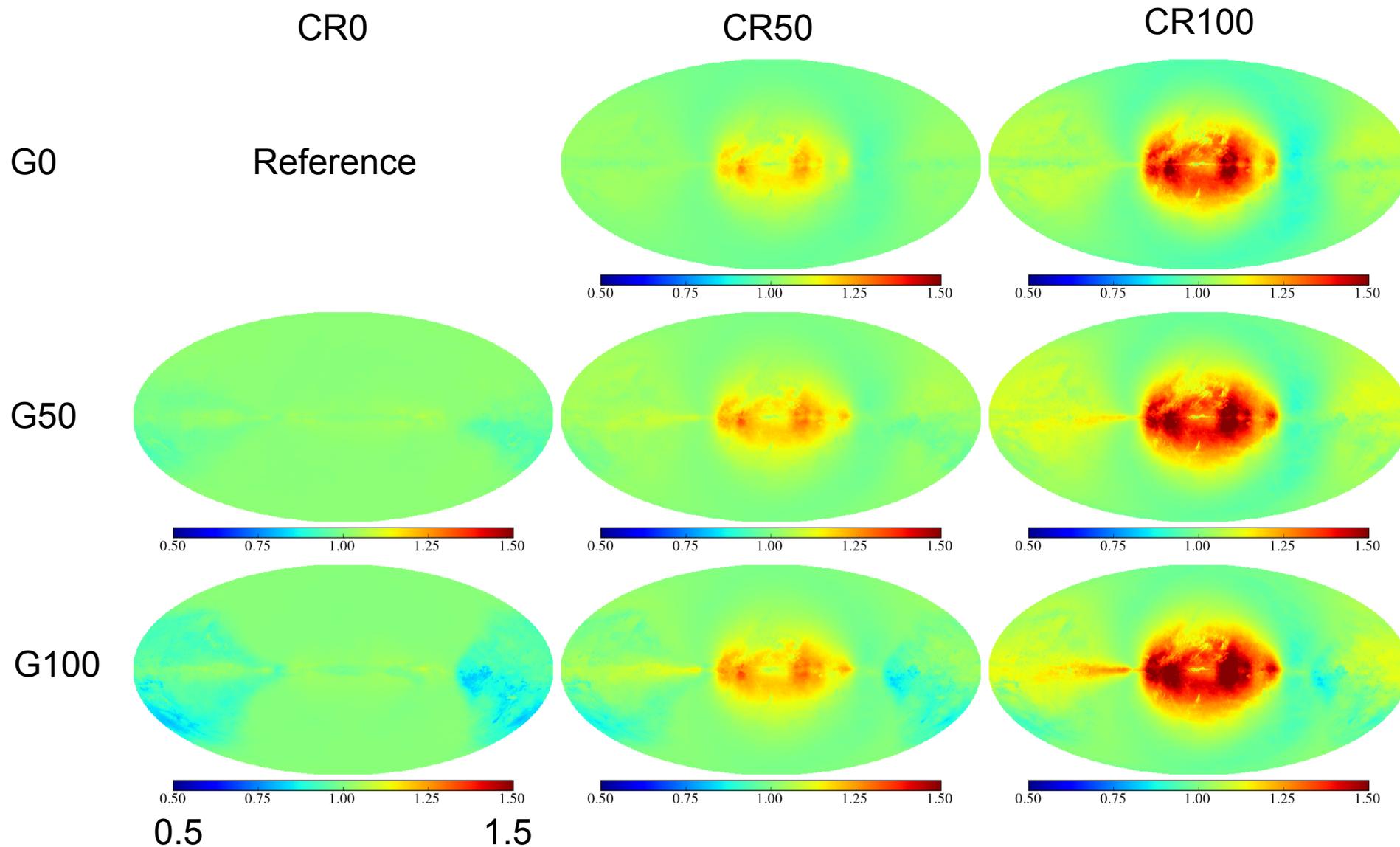
Ratio of Total IEM Model at 1 GeV



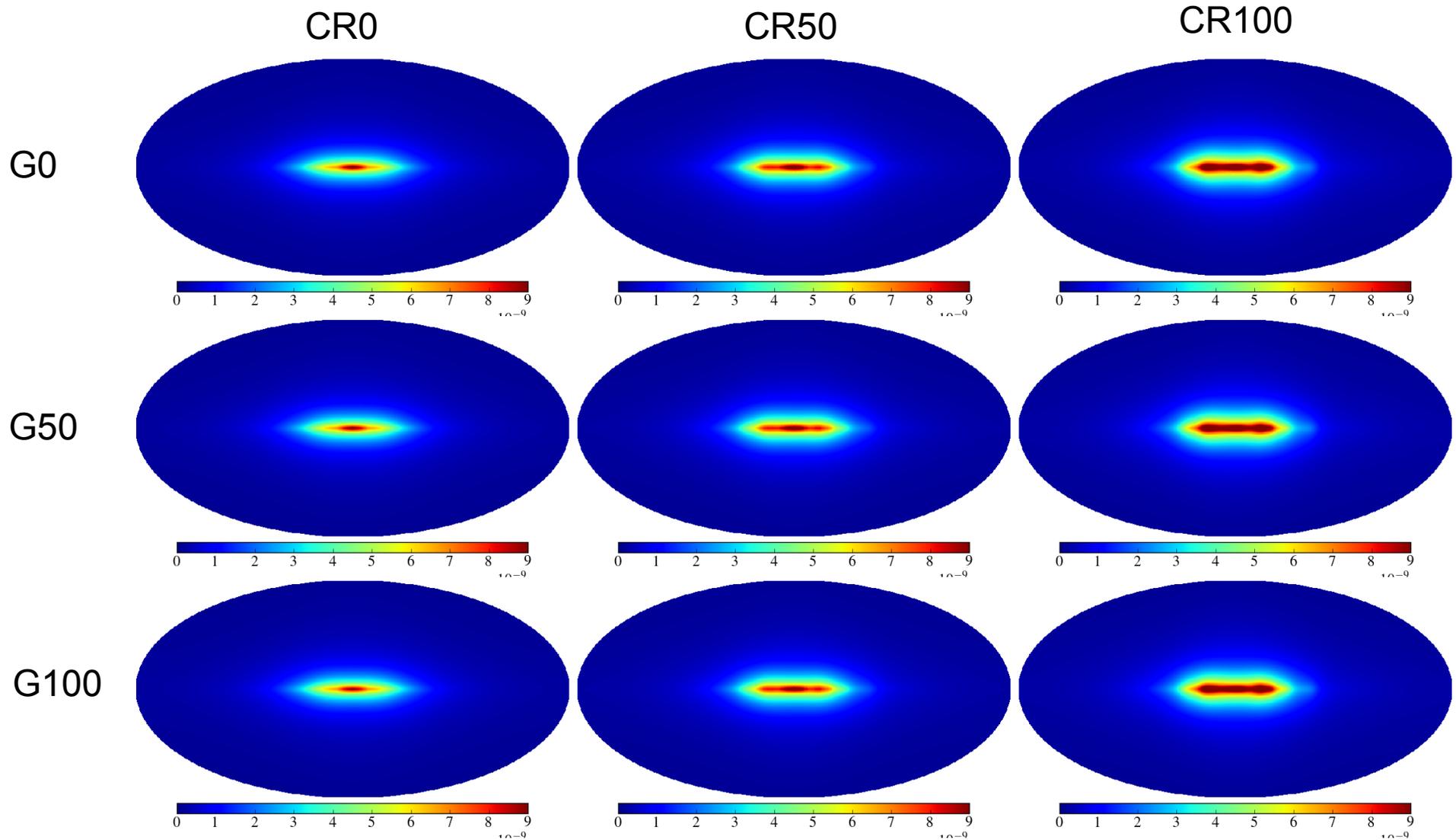
Ratio of Total IEM Model at 100 MeV



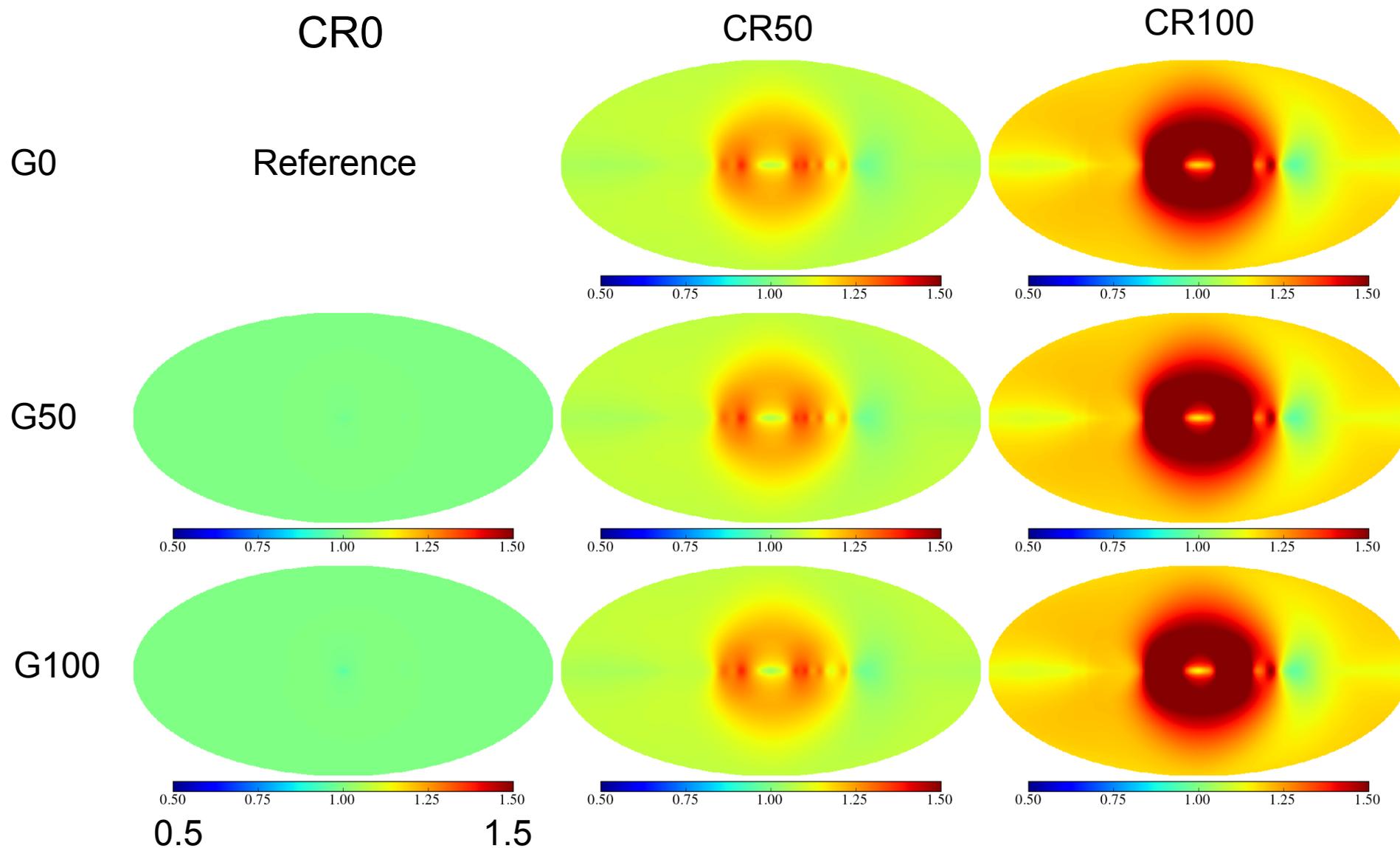
Ratio of Total IEM Model at 100 GeV



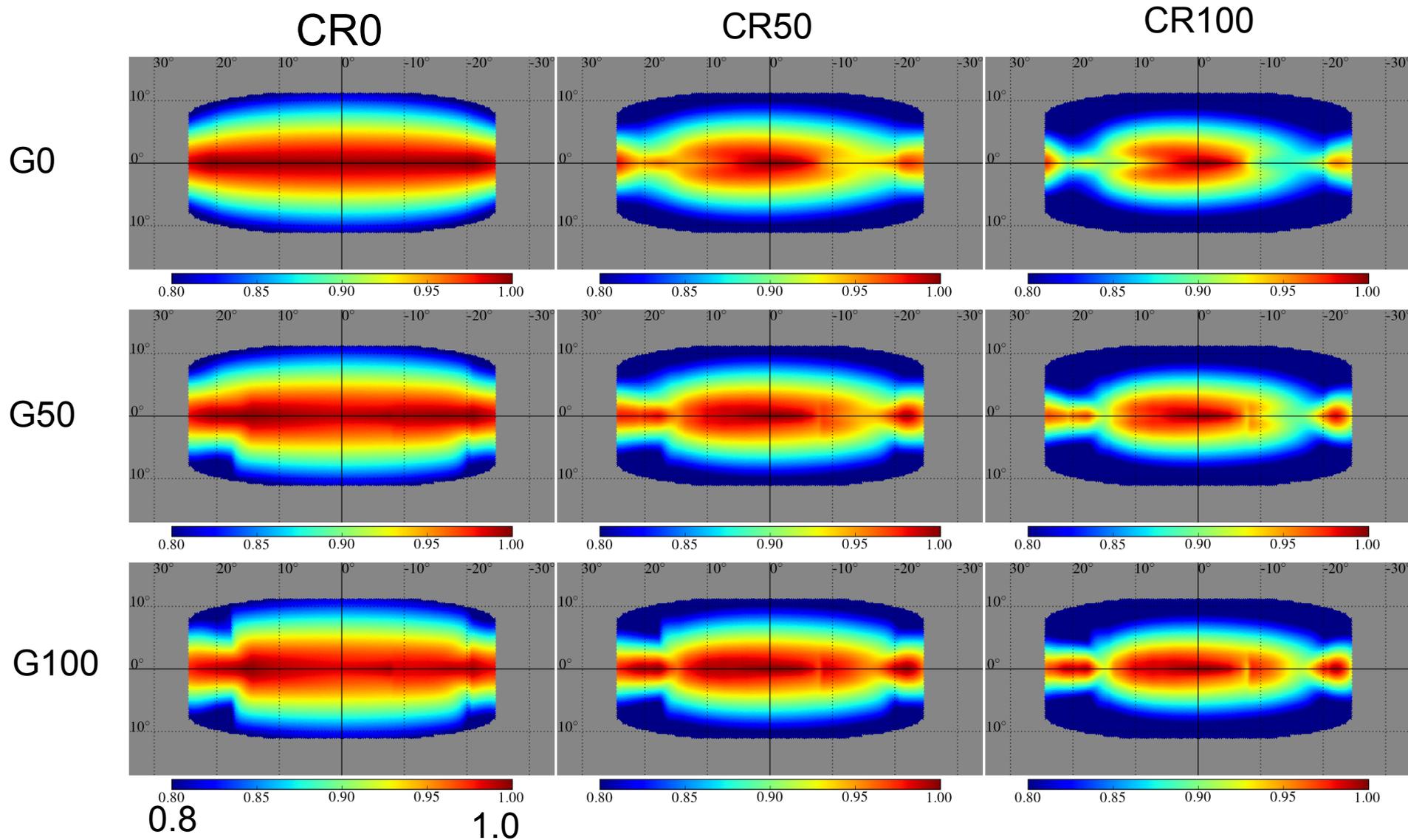
IC Intensities at 1 GeV



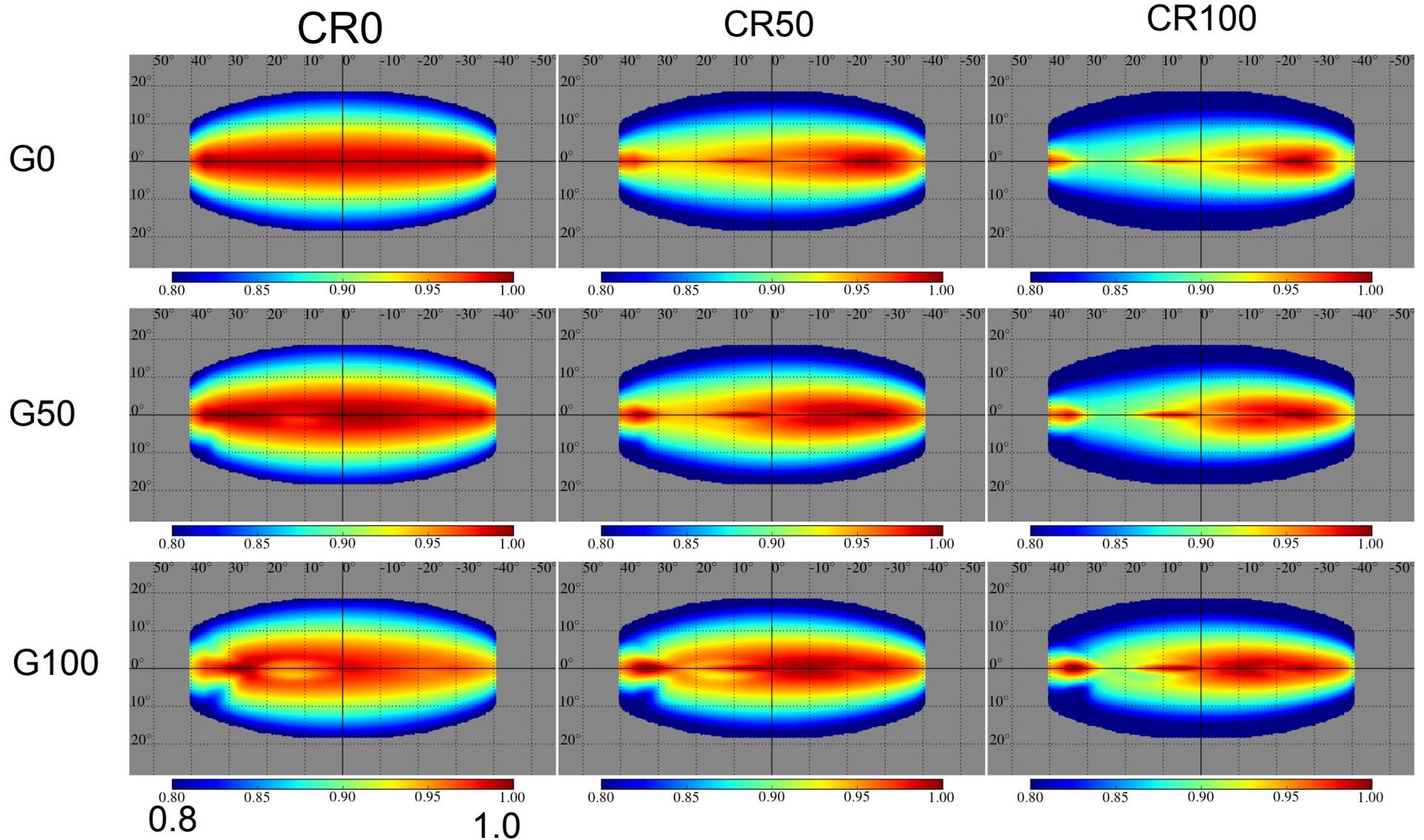
Ratio of IC intensities at 1 GeV



Gas emissivity $3.0 < R < 3.5$ kpc at 1 GeV



Gas emissivity $5.0 < R < 5.5$ kpc at 1 GeV



Summary and conclusions

- The Galaxy is not 2D axisymmetric
 - Adding simple symmetric spiral arm structure can have a significant energy dependent effect
 - Especially important when accounting for IC emission that does not have a reliable spatial template
- The models are illustrative only
 - More work is needed to tune the parameters of 3D distribution
 - Important to get constraints from multi-wavelength data